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The learning environment in clicker classrooms: student processes of learning and involvement in large university-level courses using student response systems

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To explore what social and educational infrastructure is needed to support classroom use of student response systems (Roschelle *et al.*, 2004), this study investigated the ways in which student characteristics and course design choices were related to students' assessments of the contribution of clicker use to their learning and involvement in the classroom. Survey responses of over 1500 undergraduates enrolled in seven large enrollment 'clicker courses' offered by three university departments are analyzed. A number of factors contribute to students' positive perception of clickers: a desire to be involved and engaged, a view that traditional lecture styles are not best, valuing of feedback, class standing, previous experience with lecture courses, anticipated course performance, and amount of clicker use in the classroom. These results underscore the importance of considering social and communication elements of the classroom when adopting student response technology.

Introduction

Large enrollment courses in higher education are the bane of active learning pedagogy. It is in this environment that the traditional lecture seems most appropriate, yet even the most engaging lecture is limited in how much it can support and facilitate widespread student involvement and interaction. Geski (1992), for example, noted the ways in which the physical distance between teacher and student, seating arrangements, impersonal atmosphere, and sheer number of students in large lecture classes constrain student involvement. Expressing a desire to increase interactivity in large

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classes to foster deeper learning, instructors at a number of colleges and universities are adopting student response systems, colloquially referred to as 'clickers' (in reference to the remote control keypad or handset students use to enter a response to a question).

Clickers are a simple technology. They use simple, off-the-shelf networking to send a signal from each student's handset to the instructor's computer. Clickers are also simple in that most support only one function: the multiple-choice question. However, even this basic interactivity has the potential to significantly transform the classroom experience of large enrollment courses, in which student response and individualized feedback to students typically is severely limited. Of course, adoption of a technology cannot guarantee effectiveness. Indeed, at this point, we have very little systematic information about what social and educational infrastructure is needed to support clicker use (Roschelle *et al.*, 2004). In this study, we took a first look at this infrastructure and explored the ways in which student characteristics and course design choices related to students' assessments of the contribution of clicker use to their learning and involvement in the classroom.

The challenges of teaching and learning in the large course

Teaching the large course poses a number of important pedagogical challenges. In part these challenges reflect difficulties inherent in the physical environment and size of the course. Large courses generally take place in classrooms with auditorium-style seating and significant distance from the front to the back of the classroom, creating an impersonal setting. Additionally, they include, by definition, a large number of students, most of whom are strangers to one another. This decreases students' sense of responsibility, may increase their anxiety about participating verbally in class (Gleason, 1986; Geski, 1992), and limits student–instructor interaction (Wulff *et al.*, 1987).

Other challenges tie to the traditional lecture format that typically characterizes large course pedagogy and related expectations regarding the student role. Lecture teaching tends to emphasize the instructor providing information to the students, with students remaining relatively passive (Ekeler, 1994). The teaching and learning challenges created by the structural constraints of the large course and the interaction features of the traditional lecture revolve around two central issues: learning processes and the students' role in those learning processes.

Practice, feedback, and active involvement constitute three important elements of classroom learning processes. Characteristics of the large course and lecture format create constraints for each of these elements. First, the traditional lecture limits students' opportunities to practice activities that encourage higher-order learning (Costin, 1972; McKeachie *et al.*, 1986). While lectures are useful for presenting new knowledge and modeling the application of concepts, teaching by transmitting information typically does not encourage students to engage in application, analysis, synthesis, or problem-solving in the classroom (Costin, 1972; McKeachie *et al.*, 1986; Ekeler, 1994; Cooper & Robinson, 2000a). As McKeachie put it, 'thinking,

like other skills, requires practice, particularly practice that brings our thinking into the open where it can be challenged, corrected, or encouraged' (1999, p. 327). Students need to take positions, elaborate on ideas, and think about underlying arguments in order to develop good critical thinking skills (McPeck, 1990; Rosenshine & Meister, 1995).

Second, in the traditional lecture format students rarely receive feedback concerning their thinking prior to the exam, and instructors have a difficult time assessing students' understanding of particular material. The limitations on instructor–student interaction in large courses, for example, mean that there is little opportunity to provide feedback to students during class (Wulff *et al.*, 1987). Feedback on understanding, however, is an important contributor to student learning (Nelson & Pearson, 1999) and a central principle of good practice in undergraduate education (Chickering & Gamson, 1987).

Third, the large course creates challenges for encouraging students' active participation in the learning process by limiting opportunities for student involvement. The seating arrangements, for example, make interaction with other students more difficult, and the number of students means all students cannot participate in discussion with the instructor during class (Gleason, 1986). Yet, students' participation is important in the classroom as it intersects with other elements of the learning process. Active involvement by students, for example, can facilitate critical thinking (Astin, 1993; Garside, 1996), and interaction with peers and faculty has been shown to predict positive student learning outcomes (Astin, 1993).

The structural constraints of the large course and the lecture format also shape expectations concerning the student role in the classroom. In particular, students and, sometimes, instructors view the student role as passive recipient of information (Erickson & Strommer, 1991; McKeachie, 1999). In traditional lecture formats, students are note-takers, listeners, and observers. In addition, the impersonal and anonymous nature of the large course reduces students' sense of responsibility for class interaction (Wulff *et al.*, 1987; Ward & Jenkins, 1992; McKeachie, 1999). Nelson and Pearson, for example, note that feelings 'of isolation, separation, and anonymity loom large and invite passivity, silence, and absence' (1999, p. 350) in the large course. Finally, even if opportunities are available to do so, the number of students in the classroom may create a reluctance to participate and speak in class (Gleason, 1986; Geski, 1992).

These challenges for teaching and learning in the large course become particularly important because of their relevance to student motivation and its impact on learning. Learning environments that contribute to students' motivation to learn include informational and mastery-oriented feedback, choice-making opportunities, interpersonal involvement, optimal challenge, and opportunities for students to evaluate their own and others' learning (Deci *et al.*, 1996; Perry *et al.*, 2002). Self-determination theorists argue these features of the social environment influence motivation to learn by fulfilling students' needs for autonomy (self-regulation), competence (feeling efficacious in learning activities), and relatedness (connection to others) (Deci *et al.*, 1991; Ryan & Deci, 2000). Given the impact of the large course context on these

important elements of the learning environment, instructors are likely to find it challenging to foster students' engagement in their learning.

In response to the challenges of teaching the large course, teachers and researchers have proposed a number of strategies to manage these dilemmas and encourage active participation and thinking in large classes. These include asking questions, think–pair–share activities, debates and role-plays, in-class writing assignments, and small group discussions (i.e. Bonwell, 1996; Papp & Miller, 1996; Book, 1999; Cooper & Robinson, 2000a; Butler *et al.*, 2001; Frederick, 2001) along with other classroom assessment activities (Angelo & Cross, 1993). Giving feedback on students' answers to questions or writing assignments can provide information about correct or incorrect answers and give them a chance to check their understanding (Book, 1999). Using student pair and group discussions in the large lecture presents an opportunity to break up the lecture and activate students' attention (McKeachie, 1999) and to work on more complex application and analysis tasks (Mazur, 1997; Cooper & Robinson, 2000a). In a large class, however, it becomes difficult to actively question students, given apprehension about communicating in front of large numbers of people. Challenges also exist for managing group discussions given the physical environment of the large classroom as well as the need for students to perceive themselves as responsible participants despite anonymity in the classroom.

Expanding the possibilities for teaching and learning in the large course: classroom response systems

As instructors seek to transform the learning environment of the large course from impersonal, passive, and anonymous to personal, active, and responsible, classroom response systems offer a potentially helpful teaching tool. Response systems (RSs) are used from elementary and middle school through college levels in disciplines ranging from physics and chemistry to economics and political science (Abrahamson, 1998). Physically, RSs vary in form and number of buttons. Some have 10 digits including zero and also include high and low confidence buttons to display student confidence in their answers (Elliot, 2003). Others have as many as 20 inputs for entering number, letters A–E, yes–no responses, and for requesting assistance (Ober, 1997). Some RSs even allow certain graphing calculators to function as clickers (Abrahamson, 1998). However, the essential feature of a RS is the immediate, anonymous display of the distribution of a set of student responses (Draper *et al.*, 2002). Students use clickers to transmit signals to a receiver that is connected (either by wire or wirelessly) to a computer which then processes those signals and displays in real-time the results onto a projection screen for class review and discussion.

Theoretically, RSs could transform the pedagogy of the large enrollment course. They provide an opportunity for all students in the classroom to interact and contribute their viewpoint, encourage students to actively respond to ideas and questions, and give instructors an opportunity to assess student understanding at the moment. Clicker questions can be used to accomplish a variety of pedagogical goals: assess students' understanding, give feedback on learning, initiate a classroom discussion,

stimulate student activity, explore students' responses, and customize instruction (Horowitz, 1988; Draper *et al.*, 2002). For example, one pedagogy that is directly related to the use of RSs is peer instruction (PI). As developed in the late 1980s by Eric Mazur, PI consists of lectures that 'are interspersed with short conceptual questions (ConcepTests) designed to reveal common misunderstandings and to actively engage students in lecture courses' (Fagen *et al.*, 2002, p. 206; see also Crouch & Mazur, 2001). ConcepTest questions can be given, and students can respond to them using an RS (Abrahamson, 1998).

Behind any decision to adopt an RS is a set of assumptions relating to how clickers will affect the learning environment in terms of both learning and involvement. For learning processes, a common assumption is that a clicker system is beneficial to student learning because it can provide immediate feedback. Because many implementations of clickers also involve peer teaching, there is an additional assumption that students learn well from their peers. In terms of classroom dynamics, a common goal in using clickers is to provide an alternative to the impersonal and anonymous traditional large lecture. This change in classroom culture is designed to shift the role of student from passive observer to engaged and involved participant.

Putting clickers in the hands of students, however, does not guarantee an engaged class. Critiques of such deterministic views of technology are well known (Sproull & Kiesler, 1991; Smith & Marx, 1994). Whether or not clickers transform the classroom depends upon how students respond to and use them. Given this, research on classroom response systems and the learning environment must consider what elements of the learning environment are likely to impact the success of clickers. This study focuses specifically on characteristics of students and of course design that may affect students' perceptions and use of clickers in the large class.

Student characteristics and responses to clickers

As active learning methods are incorporated into large course pedagogy, instructors frequently experience student resistance (Cooper *et al.*, 2000). In the clicker classroom, students' expectations for their role in the classroom must shift to accommodate new teaching and learning activities that encourage students to actively engage material. This is not a small shift. MacGregor (1990) noted that cooperative learning in the large course shifts student roles from listener and observer to active problem solver and contributor and creates an environment in which students have a more public, risky presence in contrast to the low-risk, anonymous presence of students in traditional large lectures. It also creates a learning environment with higher expectations for student preparation prior to class (MacGregor, 1990; Mazur, 1997). Students may also find that activities that encourage analysis and application violate expectations that the large course professor will simply provide information that they then memorize for tests.

While instructors may be motivated to incorporate response systems into the large class in order to facilitate learning and involvement, students do not necessarily share the same assumptions about what the large class should look like. Student attitudes

can function as a barrier to change (Knapper, 1987). For example, De Berry (1998) found that students in economics classes preferred the traditional lecture style over several other more innovative teaching techniques. Additionally, in their survey of students' perceptions of large classes, Wulff *et al.* (1987) noted that anonymity was a key factor in students' positive evaluation of large classes. From the student perspective, anonymity created a low-pressure, safe learning environment and also provided more flexibility in whether or not to attend class. At the same time, however, for other students the impersonal nature of the course was a factor in negative evaluations of large classes. These findings demonstrate that students vary in what they value in and expect from as well as the ways they make sense of and interpret experiences in the classroom.

Given the potential for a dramatically different role for students in the clicker classroom, accomplishing a change in learning environment depends heavily on whether students 'buy into' this goal and change their behavior accordingly. If students agree with these assumptions about the ideal learning environment, the use of clickers may capitalize on an unmet need. If they do not, clickers may actually increase student apathy and engender resistance.

- H1: Students' level of agreement with instructional assumptions motivating clicker use will positively predict students' positive perceptions of clickers' contribution to learning and involvement.

Two dimensions of student experience that seem likely to affect student assessment of clickers in the classroom are class standing and the amount of previous experience with large lecture courses. Students who are in their fourth year may have a stronger sense of a 'normal operating procedure' for a large university classroom. Consistent with this possibility, De Berry (1998) found that students increasingly preferred the lecture style in economics classes as they progressed in their degree. Additionally, the more large courses students have experienced, the more likely they are to have developed expectations concerning the student role and the less likely they may be to be open to alternative ways of doing lectures. Instructors using small group discussion in large courses noted a learning curve for students given the contrast with what they were typically used to in large courses (Cooper & Robinson, 2000b). Both class standing and experience with large courses, then, likely impact students' response to the clicker classroom.

- H2: Students with less experience in large lecture courses will have more positive perceptions of clickers' contribution to learning and involvement than students with more experience.
- H3: Students with lower class standing will have more positive assessments of clickers' contribution to learning and involvement than students with higher class standing.

Presumably, using clickers in the classroom should facilitate the type of learning environment that motivates students to learn by facilitating feedback, providing challenges, and encouraging active involvement. At the same time, however, the

incorporation of clicker questions and activities into the course grade also creates an external motivation to attend class. This may be problematic as a motivation tool if it impinges upon students' needs for self-determination and perceived competence (Deci *et al.*, 1999). Research suggests that certain types of extrinsic rewards such as completion-contingent rewards (i.e., getting points simply for answering clicker questions, regardless of whether or not the answer is right or wrong) are likely to be experienced by students as controlling and as lacking competence information. Other types of reward systems such as performance-contingent rewards (i.e., getting clicker points only for getting answers correct) also limit students' autonomy, but at the same time potentially affirm students' competence. Reducing student autonomy tends to undermine students' intrinsic motivation to learn (Ryan & Deci, 2000; Pintrich, 2003). In terms of the clicker classroom, if clicker points take away students' sense of autonomy regarding class attendance, this may negatively impact their assessments of clickers' effect on the learning environment. Higher grades than in other courses, on the other hand, may affirm students' competence and positively impact their assessments of clickers' effect on the learning environment.

- H4: Students' perceptions that clickers serve as an external motivation for attendance in lecture will negatively predict students' positive assessments of clickers' contribution to learning and involvement.
- H5: Students with expectations for better course performance compared to other classes will have more positive assessments of clickers' contribution to learning and involvement than students with expectations for lower course performance compared to other classes.

Classroom design and students' clicker assessments

In addition to students' expectations for the learning environment, instructional design choices also should influence students' perceptions that using clickers contributes to learning processes and student involvement. There is not a uniform use for clickers in the classroom. One key dimension along which course design may vary is the degree to which clickers constitute an integral part of the class design. For some courses, clicker questions and activities become the central pedagogy of the course; for others, they supplement a more traditional lecture. Two types of instructional choices that reflect variation in the integration of clickers in the classroom are the number of questions that instructors use in a particular class day and the way in which clickers are incorporated into the class grading system.

- H6: Students' perceptions of the contribution of clickers to learning and engagement should differ depending upon the amount of clicker use in the classroom.
- H7: Students' perceptions of the contribution of clickers to learning and engagement should differ depending upon how clicker points are incorporated into students' grade.

Methods

Participants

Using a previously compiled email list of approximately 20 instructors using clickers at a large public university in the Western United States, we sent a message offering to distribute surveys. We received nine responses, two of them declining participation. Of the seven who agreed to participate, three taught physics courses, two taught communication courses, and two taught astronomy courses. The instructors ranged in prior experience with using clickers and in pedagogical methods. Data were collected from six different large enrollment 'clicker' courses representing three different departments (Astrophysics, Communication, Physics). While teachers and researchers may refer to courses that range from 50 students or more under the umbrella term 'large course', we focused in this study on classes with 200 students or more.

The average enrollment for these courses was 376 students. Table 1 lists these courses.

Despite the fact that these were lower division courses, only 40.5% of the students reported being first-year students (with 30.3% reporting second year, 19.0% third year, and 9.8% fourth year). Sixteen percent had enrolled (or were enrolled) in at least one other clicker class. We also asked students how many 'large lecture' courses they had completed. Responses were fairly well distributed (0 = 3.7%, 1–2 = 32.3%, 3–4 = 30.6%, 5–6 = 17.4%, 7+ = 14.9%). We combined over 80 reported majors into 10 groups, as reported in Table 2. Not surprisingly, given our sample, Natural Sciences and Communication were the highest reported majors.

All courses used the same response system, Hyper-Interactive Teaching Technology (H-ITT; http://www.h-itt.com/). Students purchase transmitters that can be used in any course. With this system, instructors may ask any question at any time; questions do not need to be entered into the system beforehand. To use the system, the instructor poses a multiple-choice question and sets the software to receive student answers. Students answer by pressing a button (A–E) on their transmitter, which then sends an infrared (IR) signal to one of several wireless receivers mounted

Table 1. Course information

Course	Enrollment	*n*	% Response
Astronomy 1110–01	315	191	60.6
Astronomy 1110–02	320	165	51.6
Astronomy 1120	206	53	25.7
Communication 1210	350	282	80.6
Communication 1300	320	171	53.4
Physics 1110	622	336	54.0
Physics 2010	504	345	68.5
Total	2637	1543	58.5

Table 2. Number of responses by student major

Major	*n*	% Response
Communication	288	18.9
Journalism	67	4.4
Arts	56	3.7
Humanities	57	3.7
Social Science	99	6.5
Natural Science	343	22.6
Engineering	209	13.7
Business	90	5.9
Architecture	90	5.8
Open option/Undecided	222	14.6

on the classroom wall. Receivers are connected in a daisy-chain network to the instructor's computer, where the H-ITT software registers and processes the signals. Results can be displayed immediately in the form of a histogram of answers. In addition, student answers are saved in a database, which instructors may incorporate directly into their grading. All courses in this study used auditorium-style classrooms.

Procedure

All surveys were administered during class in the last week of the semester, often during the class when university course evaluations were completed. Care was taken to ensure that students understood this to be a research project specifically relating to clicker use and not associated with course evaluations. Survey answers were anonymous. Although technically possible, we consciously did not administer the survey using clickers, in order to avoid technology bias (and to get answers from students who may not have brought their clickers with them).

The first section of the survey requested demographic data, including student major, class standing, projected course grade relative to other courses, if any other clicker courses had been taken, and how many large lecture courses had been taken at the university. The remainder of the survey included items investigating students' assumptions about large lecture classes and their perceptions of and behaviors related to clickers' contributions to involvement and learning processes. The last question of the survey invited student comments. The percentage of comments was quite low; however, when they did appear these were coded for evaluations of instructor, class, or clicker. Distinctive information (information not captured by the survey items) was also recorded in a text file and used to supplement statistical analysis. Finally, each faculty member completed a short survey to collect additional information about the clicker classroom experience, including the typical number of questions used per day in each class and the incorporation of clicker activities into the grading system.

Measures

Student assumptions about large lectures. We created seven items to assess the expectations and values regarding large lecture courses that students bring to the classroom. These included assumptions about learning processes, preferences regarding the student role, and assumptions about how large lecture classes should be taught. Using a five-point scale, students indicated their agreement with each statement (see Table 3 for items and descriptive statistics). Items were recoded as needed so that higher scores reflected stronger agreement with the assumptions motivating clicker use in the classroom. Because each item was designed to assess a different assumption about large lectures, analyses used each item separately, rather than combining them into a single variable.

Desirable learning processes. Five items assessed students' perceptions and behaviors related to learning processes (see Appendix). These items contained statements concerning students' perceptions that clickers contributed to learning processes as well as statements concerning students' learning-related behavior with clickers. Students responded to the statements using a five-point Likert scale. All five items ($\alpha = .86$) were combined to measure students' perceptions of learning processes, with higher scores reflecting more positive assessments (mean = 3.73, SD = 0.95).

Classroom involvement. To assess students' sense of involvement and participation in the large lecture, six items focused on students' perceptions of and reported behaviors regarding active involvement in the class (see Appendix). These items focused on the degree to which students felt like their role as students was that of an active, engaged participant as well as their perceptions that the classroom culture as a whole was more like a small class. When necessary, items were recoded so that higher scores on the five-point scale reflected greater perceptions of involvement in classroom processes.

Table 3. Students assumptions about lecture courses

Item	Mean	SD
Getting feedback on my ideas helps me learn better	3.78	0.97
My expectation before I started this course was that I knew a majority of the material already	2.61	1.25
I prefer to be anonymous in large classes[a]	2.75	1.19
In large classes, I prefer to be involved and engaged	3.19	1.19
Classroom experiences in large courses *should* be different than classroom experiences in small courses[a]	2.46	1.15
If I had a choice, I would avoid classes where the instructor just lectures	3.09	1.24
The best way to teach large lecture courses is with the traditional lecture style[a]	3.37	1.15

[a]Indicates items that were recoded.

These six items also had acceptable reliability (α = .78) and were combined into a composite variable (mean = 3.28, SD = 0.82).

Student motivation. Two different items investigated whether or not clickers served as external motivators for attending class. The first asked students about their agreement with the statement 'for me, earning "clicker" points motivates me to come to class' (mean = 3.96, SD = 1.23), and the second asked about agreement with the statement 'I attended class when I otherwise would not have because of the clickers' (mean = 3.32, SD = 1.38). Higher scores reflect a stronger view of clicker use as an external motivator for class attendance.

Results

Student characteristics

The first five hypotheses focused on the relationship between student characteristics that may influence evaluations and use of clickers in the classroom and students reports concerning clickers' contribution to learning and involvement in the classroom.

Student assumptions about lectures. The first hypothesis proposed that students' agreement with instructional assumptions typically motivating clicker adoption would predict positively the degree to which they report positive assessments of clickers. To investigate this hypothesis, students' reports of desirable learning processes and classroom involvement served as criterion variables for two different standard regression analyses. All seven items assessing students' agreement with clicker instructional assumptions were used as predictor variables for each regression analysis.

The first regression analysis, with students' perceptions of clickers' contributions to learning processes as the criterion, was significant, although the relationship was modest ($R = .62$, $R^2 = .38$, $F(7, 1442) = 127.09$, $p < .001$). Student assumptions accounted for 38% of the variance in students' assessments of whether clickers contributed to their learning. Further examination shows five of the seven assumptions as significant predictors in the equation: beliefs that feedback contributes to learning, $\beta = .43$, $t = 18.8$, $p < .001$, preferences to be involved and engaged in large classes, $\beta = .20$, $t = 7.58$, $p < .001$, beliefs that the traditional lecture style is not the best way to teach large classes, $\beta = .23$, $t = 9.58$, $p = .001$, preferences for less anonymity in large classes, $\beta = -.16$, $t = -2.72$, $p < .01$, and desire to avoid straight lecture classes if possible, $\beta = -.05$, $t = -2.11$, $p < .05$. The first three relationships were in the expected direction. While preferences for less anonymity and avoiding straight lecture negatively predicted perceptions of learning processes, these negative relationships likely reflect suppression effects since the zero-order correlation between preferences for less anonymity and learning ($r = .05$, $p < .05$) and the correlation between preferences for avoiding straight lecture and learning ($r = .18$, $p < .01$) were statistically significant and positive.

Student perceptions and behaviors related to involvement served as the criterion variable for the second regression analysis. Several student assumptions were significant predictors of involvement with modest correlations, $R = .61$, $R^2 = .37$, $F(7, 1422) = 119.23$, $p < .001$. As with learning processes, beliefs that feedback contributes to learning, $\beta = .32$, $t = 13.82$, $p < .001$, preferences to be involved and engaged in large classes, $\beta = .30$, $t = 11.33$, $p < .001$, and beliefs that the traditional lecture style is not the best way to teach large classes, $\beta = .23$, $t = 9.27$, $p < .001$ were all significant positive predictors of students' perceptions that clickers created an engaged, active learning environment.

Hypothesis 1 was supported. Not surprisingly, students who indicated a higher preference for being involved and engaged in the large course were more likely to perceive clickers positively and engage in desirable clicker behaviors. Additionally, students who placed a greater value on feedback reported more positive assessments of clickers in terms of both learning processes and involvement. Finally, beliefs that the traditional lecture style is not the best way to teach large courses predicted positive perceptions and behaviors toward clickers.

Lecture experience and class standing. Hypothesis 2 predicted an inverse relationship between student experience with large lectures and positive assessment of clickers' contribution to learning processes and involvement. Hypothesis 3 predicted that students with lower class standing would have more positive perceptions than students with higher class standing. Given the likely interdependence of class standing and lecture experience, two separate factorial ANOVAs were run with class standing and lecture experience as independent variables and reports of learning and reports of involvement as dependent variables to test hypotheses 2 and 3. Students' evaluation of learning processes differed significantly for both number of large lecture classes students had ($F(4, 1468) = 2.44$, $p < .05$) and class standing ($F(3, 1468) = 2.78$, $p < .05$). There were no significant interaction effects.

Bonferroni *post hoc* analyses indicated that students with 5–6 (mean = 3.52) and 7+ (mean = 3.50) lecture classes differed significantly from students who had taken 0 (mean = 3.92), 1–2 (mean = 3.88) or 3–4 (mean = 3.75) large courses. In terms of class standing, first-year (mean = 3.87) and second-year (mean = 3.81) students differed from third-year (mean = 3.44) and fourth-year (mean = 3.39) students in their evaluation of clicker's contribution to learning. A second factorial ANOVA indicated no significant differences in students' assessment of involvement by experience with large lectures or class standing.

Both hypotheses 2 and 3, then, were partially supported. As expected, first- and second-year students perceived greater learning with clickers than did third- and fourth-year students. Additionally, more experience with lecture classes meant that students had a lower assessment of the learning being done with clickers. Contrary to expectations, however, no differences were identified for involvement.

External motivation. The fourth hypothesis proposed a negative relationship between the degree to which clicker points served as external motivators for attending class

and students' assessments of clickers' contribution to learning processes and involvement. Pearson product-moment correlations indicate a positive relationship between students' report that points motivate attendance and both perceptions of learning processes ($r = .45$, $p < .01$) and involvement ($r = .43$, $p < .01$). In contrast, there was no significant relationship between students' report that they attended class when they otherwise would not and their assessment of clickers and learning processes ($r = .02$, NS). The correlation with perceptions of involvement was significant at the .05 level, but practically speaking quite small ($r = .06$). Hypothesis 4, then, was not supported.

Student performance. The final hypothesis concerning student characteristics considered the possibility that students' assessment of their performance would influence their perceptions of the learning processes and their involvement. Performance was measured by students' expectation for a grade in the clicker class relative to their grades in other classes (lower, similar, or higher). A one-way ANOVA with students' assessment of learning as the dependent variable indicated differences among students expecting lower (mean = 3.37), similar (mean = 3.83), or higher (mean = 4.12) grades compared to other classes ($F(2, 1493) = 33.03$, $p < .001$). Bonferroni *post hoc* analyses indicated that all three groups differed significantly from one another on assessments of learning processes. In a second one-way ANOVA with involvement as the dependent variable, differences were also identified among students expecting lower (mean = 3.01), similar (mean = 3.37), and higher (mean = 3.58) grades in this class compared to other classes ($F(2, 1469) = 45.01$, $p < .001$). Bonferroni *post hoc* analyses indicated that all three groups differed significantly from one another in terms of involvement. Students expecting lower grades had lower assessments of both learning and involvement than students expecting similar grades and students expecting grades similar to other classes had lower assessments of learning and involvement than students expecting better grades. Hypothesis 5 was supported.

Course design

In addition to ways in which student characteristics may influence students' evaluations of clickers, it is also possible that the course structure may affect assessments of clickers in the large course.

The amount of clicker use within classes. Faculty reported using clickers to a varying degree. Hypothesis 6 proposed that frequency of use would relate to whether or not students responded favorably to clickers. Using learning processes and involvement measures as dependent variables, we conducted two separate one-way ANOVAs with courses grouped according to the number of clicker questions typically used within a class day (1–3, 4–6, 7–9).

Results indicate a significant difference among groups for both reports of learning processes, $F(2, 1504) = 155.32$, $p < .001$, and reports of involvement, $F(2, 1480) =$

183.60, $p < .001$. Bonferroni *post hoc* analyses indicated a significant difference in reports of learning-related perceptions and behaviors among classes using 1–3 questions (mean = 3.30), 4–6 questions (mean = 4.14), and 7–9 questions (mean = 3.97). For involvement, classes using 1–3 questions (mean = 2.88) differed significantly from classes using 4–6 questions (mean = 3.59) and 7–9 questions (mean = 3.65), but the latter two groups did not differ significantly from one another. Hypothesis 6 was supported.

The incorporation of clicker points in grades. Hypothesis 7 explored the relationship between grading structure and student perceptions of the clicker learning environment. Courses were grouped according to whether or not points for clicker questions were (1) extra credit or (2) incorporated into the course grade. For this analysis, we excluded responses from students in Communication 1210 because clickers were incorporated into the grading policies on a much smaller level than other courses. Two different one-way ANOVAs were run with learning perceptions and involvement as the dependent variables. No significant differences were identified between courses with extra credit (mean = 3.91) and those with points incorporated into the class grade (mean = 3.95) for learning perceptions. For involvement, however, the difference between courses with extra credit (mean = 3.41) and those with class points (mean = 3.52) was statistically significant, $F(1, 1209) = 5.99$, $p < .05$. Hypothesis 7, then, was partially supported, although the difference was not large.

Discussion

The results of this study suggest a tempering of the arguments supporting RS adoption in university classrooms. For example, Draper *et al.* (2002) argue that RSs allow students to 'affect the course of what happens next' in a course, and, in so doing, increase student motivation. Our findings suggest that students may not wholly embrace this vision of their role as active participants and that, for some students, clickers may more clearly affect external rather than internal motivation (i.e., through grades). On the other hand, students who do value feedback, do not value a traditional lecture style, and prefer to be engaged and involved in the large classroom tend to be more positive about clickers.

Clickers and student expectations

The use of clickers assumes that students will find the kind of feedback that clickers provide to be helpful for the learning process. The pattern of findings in our analysis of student assumptions about the large course suggests that the information students get from clicker questions will be perceived as more useful for learning if the student already understands and values feedback in general. Whether or not students see the value of feedback generally also may motivate careful, considered clicker-related

behavior and involvement in the classroom activity. Students need to see the relevance of the clicker activity for their learning.

Our pattern of findings also suggests that the degree to which the behaviors required in a 'clicker classroom' violate students' expectations and preferences for how a large lecture class should operate impacts their perceptions and (more importantly) their classroom behavior. The clicker itself does not ensure engaged, active students in the classroom, but rather is a tool that may facilitate that process, depending in part upon the expectations that students bring to the large lecture class. Descriptive statistics indicate variation in both students' preference for being involved and engaged in the large course and their belief that the traditional lecture style is not best, with averages close to the midpoint of the five-point scale. If students want to be involved and engaged, they are more likely to perceive clickers positively in terms of both learning and involvement processes.

One interpretation of these findings is that students see beyond the technology, to recognize the deeper issue of an instructor's pedagogical commitments. Students may not respond positively if they do not see the use of clickers as necessary to an instructor's pedagogical style. Additionally, this suggests that instructional strategies focused on changing students' beliefs about large course pedagogy may increase clicker effectiveness, beyond the general use of active learning strategies. For example, instructors may need to work to explicitly frame the clickers in terms of their benefits to the class and to student learning. Future studies should investigate the effectiveness of such framing strategies, including how early the framing is done, with what frequency, and through which media (e.g., class lecture, course websites, syllabi).

In addition to the overall expectations that students bring to the large course, the findings regarding class standing and lecture experience support De Berry's (1998) research with economics courses, suggesting it is possible that as students become socialized into the university and experience traditional large course structures, they may be more resistant to changes in learning processes. While these differences were small, they do suggest further attention might be paid to the ways in which students' past class experiences impact their evaluation of clicker classrooms, particularly in terms of understanding whether or not learning is occurring as a result.

Given the fact that all of these classes are lower division courses, the more negative attitudes of upper division students to clicker use may reflect, in part, a negative response to the fact that attending lecture impacts their grade. In fact, two one-way ANOVAs with the two 'clicker motivation' items as dependent variables indicated clicker points were less likely to motivate attendance for fourth-year students than for first- and second-year students, and fourth-year students were less likely than second-year students to attend class when they otherwise would not.

Clickers and motivation to learn

Whereas attendance typically goes unrecognized in the grading system of large courses, clicker points create an external reward for students' attendance. In this study, we found that students generally reported that clicker points motivated

attendance and, to a lesser degree, encouraged their attendance when they otherwise would not come. A follow-up analysis indicates that the way in which clicker points are structured in the class grade impacts the degree to which it functions as a motivator for attendance. Depending upon whether clicker points were extra credit or part of the course grade, there was a significant difference in the degree to which students reported that points motivated their attendance, $t(1258) = 6.62$, $p < .001$ (extra credit, mean = 3.87; part of grade, mean = 4.29) and a significant difference in students' report of the degree to which they attended class when they otherwise would not, $t(1252) = 4.03$, $p < .001$ (extra credit, mean = 3.15; part of grade, mean = 3.49). This is consistent with earlier studies that found using clickers increases student attendance. Burnstein and Lederman (2001), for example, found that when RS participation counted for greater than 15% of a student's grade, attendance levels were around 80–90% and that students make genuine attempts to prepare for quizzes and to remain alert throughout the lecture. Woods and Chiu (2003) found similar results when they made RS participation worth 5–10% of the course grade.

As an external reward system, however, we expected clicker points to diminish students' sense of autonomy and undermine their internal motivation to learn. Contrary to expectations, however, students who found clicker points more motivating for attendance reported more positive judgments of clickers and their use in the classroom. Rather than an external motivation, this question may have tapped into an internal motivation to come to class created by interesting and engaging active learning practices. At the same time, however, an item focused specifically on students who attended when they otherwise would not have did not correlate with learning processes and had only a minimal correlation with involvement.

In contrast, students expecting lower grades had a lower average on both assessments of learning and assessments of involvement. There are several possible explanations for this, including the expectation that involvement and engagement in class should lead to better performance in the course and that treating clickers seriously as a learning tool (i.e., taking clicker questions seriously, seeing the ways in which they contribute feedback about understanding) should also lead to a better performance in the course. It is also possible that students who do not do as well as they typically perform in other courses were disengaged. It is possible that at least some of these students had expectations about what a 1000 or 2000 level large lecture course should look like and were resistant to a change in that.

Clickers and course design

We did find that the use of clickers was consistent with some of the findings reported by Ober (1997), including improved attendance. However, the element presumed most distinctive to the clicker classroom—interaction—received only mixed support. The level of interactivity in the classroom is highly dependent on the instructor's pedagogy. In particular, pedagogical differences in the integration of clicker questions into the class design related to differences in students' views that clickers contribute to learning processes and to class involvement. For some courses, clicker questions

and activities become the central pedagogy of the course; for others, they supplement a more traditional lecture. Some instructors in our study relied almost exclusively on peer-to-peer interaction, while others maintained the model of student–teacher interaction. Although the number of clicker questions asked in a class period does not capture student perceptions of how clickers reflected a distinctive pedagogical style, in open-text responses, students clearly recognized when this was the case. Students were apathetic or negative toward clickers when the technology did not change the classroom experience in a self-evident manner. Students need to be able to accomplish different things through the use of clicker questions than could be accomplished by simply listening to a lecture of the same material. This is similar to the challenge of making lecture extend beyond material found in the textbook.

Limitations

We recognize that this study has a number of limitations. First, the survey was given only at the very end of the semester. It would be very instructive to track the learning environment throughout the semester, and to survey students at least at the beginning and end of the course. Second, the measures of student assumptions were single-item assessments. However, our results suggest that our approach—using key variables to measure and assess the learning environment—is instructive. Third, open-ended comments on collected surveys suggested a number of questions that should have been included as items, such as a general score for satisfaction with clickers, questions concerning levels of students' anxiety with the technology and their learning, and questions relating to the technology itself (including cost and perceived reliability). In further studies we will refine the survey instrument.

Conclusion

Clickers do not necessarily tap an unmet need or desire in students to avoid the experience of the large classroom. Yet, from an instructional viewpoint, there are advantages to developing alternatives to the traditional lecture. Complexity arises because students are not only accustomed to the large lecture (and their responsibilities therein), they also may prefer the lecture for the way it fits with their learning style. From this study, it appears that while 'clicker classrooms' are certainly not large lectures, neither do they provide the experience of a small seminar. In fact, they do not appear to be one thing at all. One reason this may be the case is that clickers are a tool that can support many pedagogical approaches. Indeed, the correlations reported in this study suggest that the predictive factors influencing RS effectiveness are likely to be highly variable, yet patterned. Thus, further exploration of factors relating to teacher attitudes and experience, course content, and student expectations would be beneficial. Further studies should investigate these variations.

Clickers are an unusual educational technology. Unlike websites, PowerPoint, or even course management tools such WebCT and Blackboard, the success of clickers depends less on the instructor and more on the student because clickers require a

change not simply in the mode of communication between instructors and students or in the availability of information, but in the very culture of the classroom environment. In other words, the final effectiveness of the clicker will rest with each student accepting the potential of clickers to positively affect their learning. The success of the clickers is in many ways dependent on social, not technological, factors. Instructors must work to facilitate student acceptance and to frame student perceptions of the technology. Students must use them skillfully and faithfully. Students must also embrace the ways that clickers will change their learning experience. As an educational tool, clickers do not simply augment the classroom, they *transform* it because of the new responsibilities given to students to guide and affect classroom dynamics.

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Appendix

Learning items

1. By using clickers in this class, I got feedback on my understanding of class material.
2. Clicker *questions* helped me to know how well I was learning the material.
3. Clicker *questions* were helpful for preparing me for the exams in class.
4. I choose my answer to each clicker question carefully.
5. I pay attention to whether or not my answer to a clicker question was right or wrong.

Engagement items

1. Clicker *questions* encouraged me to be more engaged in the classroom process.
2. I actively participate during class.
3. The use of clickers helped my experience in this class to be more like the experience of a small class.
4. The use of clickers in this class has made me feel less anonymous.
5. Sometimes during a class, students were asked to discuss material with each other. Because the class used clickers, we discussed the material more seriously.
6. Often I feel withdrawn or distant during interactions in this class. (recoded)